Comparison of two machine-learning methods to predict intervertebral disc properties

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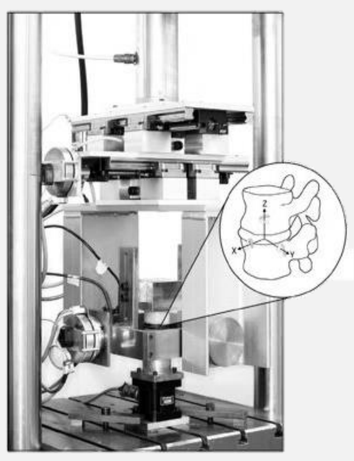
Introduction

Evolutionary polynomial regression (EPR) uses a genetic algorithm and least square regression to learn complex relationships in the form of clear transparent mathematical equations [1, 2], providing benefits over black-box artificial neural networks (ANN).

EPR may help define intervertebral disc (IVD) material properties for FE modelling, which have been approximated in different ways, often generically. Improved subject-specific IVD representation would aid understanding of spinal loading. This study aimed to compare the accuracy of EPR with ANN in predicting IVD mechanical properties.

Methods

This study used previously collected 6-axis *in vitro* data of six porcine IVD specimens [3]. The data contained applied translations/rotations, with corresponding forces/moments (Fig. 1).



Translation/Rotation Inputs

TX: Anteroposterior shear | RX: Lateral bending

TY: Lateral shear | RY: Flexion/ extension

TZ: Compression | RZ: Axial rotation

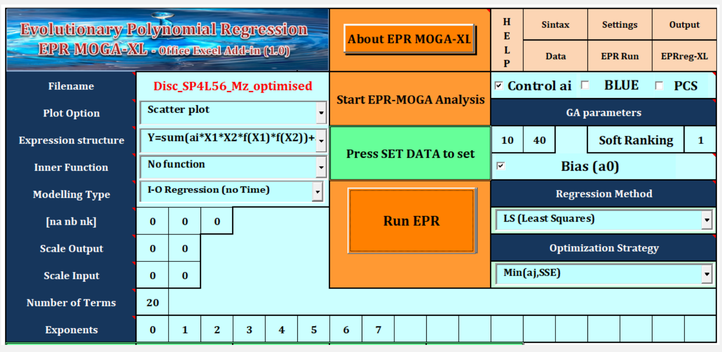
FX, FY, FZ, MX, MY, MZ

Force/Moment Outputs

Figure 1: Intervertebral disc 6-axis mechanical test data [3]

EPR (EPR-MOGA-XL, v1.0 [1, 2]) and ANN (MATLAB, R2022a) were used to predict each specimen-specific force/moment output from all translation and rotation inputs, allowing coupled motions. Both methods used a 60/40% ratio for training/test data, and software parameters were optimized (Fig. 2).

EPR:



ANN:

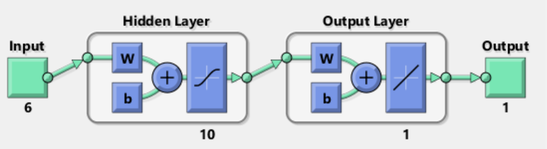


Figure 2: EPR software interface and parameters, and ANN structure

Acknowledgements and References

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1. Giustolisi O, Savic DA. J. Hydroinformatics. 2006; 8(3): 207-222.
2. Giustolisi O, Savic DA. J. Hydroinformatics. 2009; 11(3): 225-236.
3. Holsgrove TP et al., Spine J. 2015; 15(1): 176-184

Results

EPR produces multiple equations to allow balance between model complexity and accuracy. Fig. 3 shows examples of the EPR models produced for a specimen, that were within 0.5% R^2 of the best fitting model for that axis.

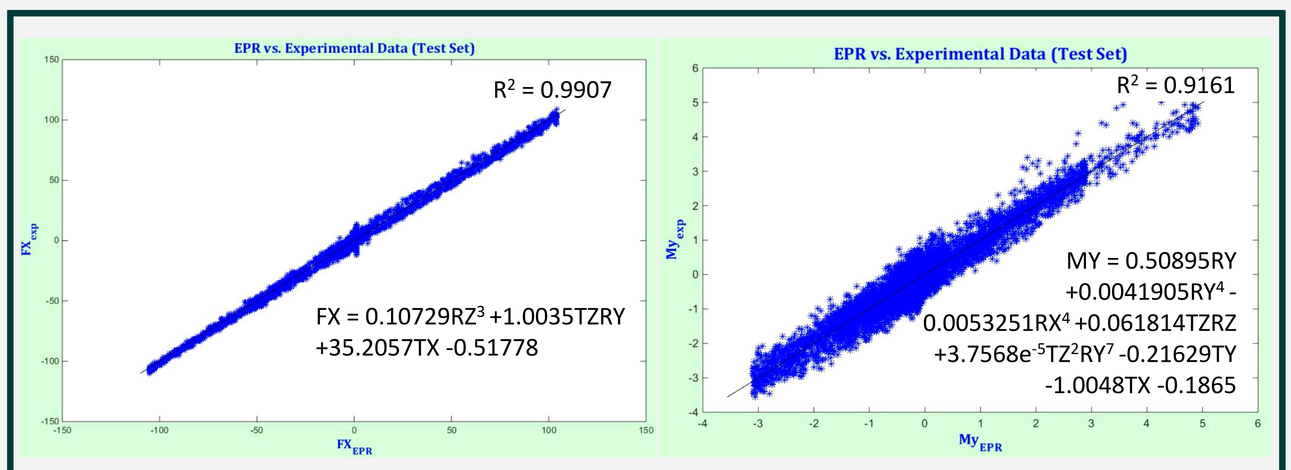

Figure 3: Example EPR results for specimen SP1 for FX (left) and MY (right)

The R^2 and normalised mean square error (NMSE) of both methods were compared for each axis (Fig. 4), with the following findings:

- Most models had R^2 values above 0.85, across all specimens and axes,
- ANN tended to perform better than EPR though differences were limited in most axes,
- The greatest differences between methods were in compression (FZ):

	R^2	NMSE
FZ (compression)	0.024 – 0.071	3.54 – 10.72
All other axes	-0.003 – 0.016	-0.002 – 0.076

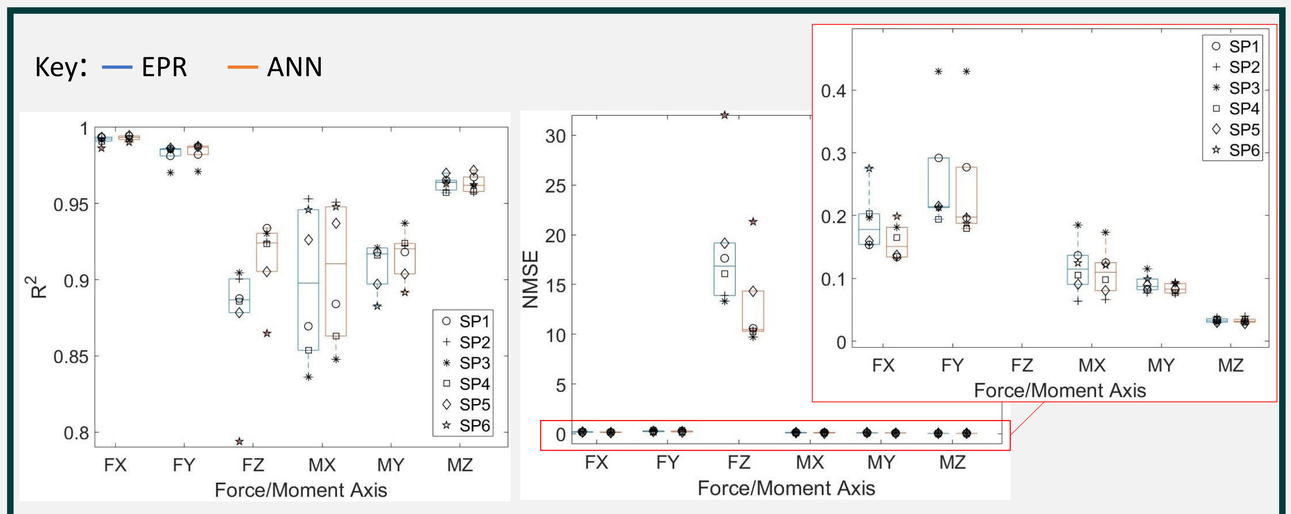

Figure 4: Comparison of EPR and ANN model accuracy for the 6 IVD specimens (SP1-6)

Discussion and Next Steps

- Both ANN and EPR methods predicted IVD properties with a high degree of accuracy.
- Although the ANN models were usually more accurate, the differences were often small, so may not have a biomechanical impact.
- The lower accuracy in compression (FZ) may be due to IVD creep which was unaccounted for in the models.
- This work will be built upon to predict IVD mechanical properties from MR data, developing a prediction model using *in vitro* specimens, then applying the model to *in vivo* data.
- FE modelling utilizing these subject-specific disc properties could improve knowledge of spinal loading.

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